Provincial Report

Physics 30
Grade 12 Diploma Examination

September 1984

Student Evaluation

Alberta
EDUCATION

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PREFACE

This report presents the provincial results of the Physics 30 Diploma Examination administered on June 27, 1984. During this second administration, the Physics 30 Diploma Examination was written by 4905 students. This report provides information about the examination development process, the examination itself, and the examination results.

ACKNOWLEDGMENTS

This second administration of the Physics 30 Diploma Examination was successful due to the concerted effort of all involved. Success would have been impossible without substantial contributions from many people, particularly the administrators, teachers, and students, who extended their full co-operation.

The technical expertise and advice received from the Examination Review Committee regarding design, development, and reporting have been particularly valuable in the implementation of this diploma examination. This Committee has representation from:

The Alberta Teachers' Association
The Conference of Alberta School Superintendents
The Universities Co-ordinating Council
The Public Colleges of Alberta
Alberta Education

The contribution of this group is gratefully acknowledged.

Lloyd E. Symyrozum
Director
Student Evaluation Branch

CHAPTER 1

Grade 12 Diploma Examinations Program

Introduction

All Grade 12 students in Alberta are now required to write at least ONE diploma examination to receive a high school diploma. Mature students may receive credits for a Grade 12 course by writing the appropriate diploma examination. They are not required to be registered in the course. The Grade 12 Diploma Examinations Program, which is an integral part of the high school diploma requirements, is intended to develop and maintain excellence in educational standards through certification of academic achievement.

The Diploma Examinations Program consists of course-specific examinations that are based on the prescribed *Program of Studies for Senior High Schools* for the following Grade 12 courses: English 30, English 33, Social Studies 30, Mathematics 30, Biology 30, Chemistry 30, and Physics 30.

Alberta Education issues two distinct high school diplomas: the General High School Diploma and the Advanced High School Diploma.

General High School Diploma

To earn a General High School Diploma, a student must obtain course credit in either English 30 or English 33, and obtain 100 credits distributed over courses as specified in the *Junior-Senior High School Handbook*. Some students who are working toward the general diploma may wish to obtain credits in other diploma examination courses (i.e., Social Studies 30, Mathematics 30, Biology 30, Chemistry 30, and Physics 30). To obtain credits in these courses, a student must also write the appropriate diploma examination regardless of the type of diploma he wishes to receive.

Advanced High School Diploma

The Advanced High School Diploma represents achievement in an academic program that includes language arts (English), social studies, mathematics, and science. To earn an Advanced High School Diploma, a student must satisfy the current course and credit requirements for a General High School Diploma, and obtain course credits in English 30, Social Studies 30, Mathematics 30, and ONE of Biology 30, Chemistry 30, or Physics 30.

Awarding of Course Credits

Grade 10 and Grade 11 Courses. To obtain credits in Grade 10 (10-level) and Grade 11 (20-level) courses, a student must earn a final mark of 40% or better. A student who has achieved a mark of 50% or higher in a given course is eligible to take the next or higher-rank high school course in that sequence.

Grade 12 Courses. To obtain credit in a Grade 12 (30-level) course, a student must earn a final mark of 50% or better. To obtain credit in a Grade 12 diploma examination course, a student must write the appropriate diploma examination and attain a final blended mark of 50% or better. The final blended mark is made up of 50% of the mark awarded by the school and 50% of the diploma examination mark. For example, a student taking Physics 30 might have a mark of 45% from his school and a mark of 57% on the diploma examination. This student would earn credits for Physics 30 because his final mark would be 51%, which is the average of the school and examination marks. For mature students who do not have a school mark or who have a school mark lower than the examination mark, the examination mark is the final mark.

Transitional Provisions

During the 1983/84 school year, Alberta Education will recognize all course credits earned prior to September 1, 1983, for the purpose of awarding the General High School Diploma.

A student who has completed partial requirements for the Advanced High School Diploma prior to September 1, 1983, and who is enrolled in Grade 12 courses during the 1983/84 school year, may apply any of the previously completed required diploma examination subjects toward a diploma provided that the student has earned a final course mark of 50% or better in each subject.

Award of Excellence

When candidates for an Advanced High School Diploma obtain a final average of 80% or higher on the four required diploma examination courses with not less than 65% in any one of these four required courses, they receive an Award of Excellence. This Award of Excellence is noted on the student's Advanced High School Diploma.

When a student writes two or three of the diploma examinations in Biology 30, Chemistry 30, and Physics 30, the highest of these final course marks is used for diploma purposes and in the calculation of the average for the Award of Excellence.

CHAPTER 2

Description of the Examination

This chapter outlines the procedures that were followed during examination development and describes the structure and content of the examination. Sample questions from the June 1984 examination are included.

Examination Development

There were three stages in the development of the June 1984 Physics 30 Diploma Examination: preparation of curriculum specifications, development of questions, and selection of questions for the final copy.

1. Curriculum Specifications

   The Curriculum Branch of Alberta Education prepared curriculum specifications based on the topical outline of the Physics 30 core described in the *Program of Studies for Senior High Schools*. In these specifications, weightings were assigned to each major content area and to specific topics outlined in the *Program of Studies*. These weightings were based on the emphasis that each topic was to receive in the Physics 30 program. The curriculum specifications were distributed to all school jurisdictions in the province.

   Topic statements upon which specific questions were based, along with sample questions for each topic, are given in this chapter.*

2. Development of Questions

   Committees composed of teachers and Student Evaluation Branch personnel constructed questions to reflect the content statements listed in the curriculum specifications. The questions were field-tested, and revisions were made on the basis of teacher recommendations and the field-test results.

3. Final Copy

   A test development specialist, assisted by groups of classroom teachers, built the examination from suitable questions. These committees selected questions from various content areas so that each area received the emphasis recommended in the curriculum specifications. An Examination Review Committee checked the proposed examination for content validity, accuracy, and technical merit, and further changes were made in accordance with their recommendations.

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*The topic statements in this report are taken directly from *Curriculum Specifications for Physics 30* (July 1983).

Examination Description

On the Physics 30 Diploma Examination, each content area received the following emphasis:

Content Area	Emphasis in % of the Total Examination Mark
Nature and Behavior of Light	20
Electric and Magnetic Fields	26
Electromagnetic Radiation	20
Structure of Matter	20
Modern Physical Theories	14

To the extent that paper-and-pencil testing permitted, the Physics 30 Diploma Examination assessed the application of the scientific process skills of classifying, inferring, predicting, hypothesizing, interpreting data, controlling variables, and processing data. The questions that are readily identified with specific process skills are listed below.

Process Skill	Multiple-Choice Question	Written-Response Question
Classifying	31	
Inferring		4
Predicting	6, 12	
Hypothesizing	30	
Interpreting Data		1
Controlling Variables	17, 25, 39	1
Processing Data	23	

Understandably, the experiences gained by direct, hands-on activities are difficult to measure outside a laboratory situation and should therefore be reflected in student performance as evaluated by the teacher.

Subject matter in the attitudinal and psychomotor components of the program was also excluded from the diploma examination.

The time allotted for writing the Physics 30 Diploma Examination was two and one-half hours. The examination consisted of both multiple-choice questions (worth 80% of the total examination mark) and written-response questions (worth 20% of the total examination mark). There were 55 multiple-choice questions worth one mark each and three written-response questions worth a total of 15 marks.

The classification of examination questions according to content area and cognitive level is presented in Table 1.

Table 1

June 1984 Physics 30 Diploma Examination Blueprint

Subject Matter Area	Question by Cognitive Level			Examination Emphasis
	Knowledge	Application and Understanding	Higher Mental Activities	
Light	1,7,10,11	3,4,5,8,9 [1]	2,6	20%
Electric and Magnetic Fields	13,15,16,18, 19,21,22,24	12,14,17,20 [3]	23,25	26%
EM Radiation	26,28,36	27,29,30,31, 34,35 [1]	32,33	20%
Structure of Matter	40,41,46,47	37,38,39,42, 44 [4]	43,45	20%
Modern Physical Theories	48,51,53,54	49,50,52,55	[2]	14%
Examination Emphasis	35%	50%	15%	100%

Note: Numbers in brackets [ ] indicate the written-response questions. Some written-response questions cover more than one topic.

Explanation of Blueprint Thought Levels

1. Knowledge

   Knowledge is defined as including those behaviors and examination situations that emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena. Incorporated at this level is knowledge of terminology, specific facts (dates, events, persons, etc.), conventions, classifications and categories, methods of inquiry, principles and generalizations, and theories and structures.

2. Application and Understanding

   Application requires the student to apply an appropriate abstraction (theory, principle, idea, method) to a new situation.

   Understanding refers to responses that represent a comprehension of the literal message contained in a communication. This means that the student is able to translate, interpret, or extrapolate. Translation refers to the ability to put a communication into another language. Interpretation involves the reordering of ideas (inferences, generalizations, or summaries). Extrapolation includes estimating or predicting based on an understanding of trends or tendencies.

3. Higher Mental Activities

   Included in higher mental activities are the processes of analysis, synthesis, and evaluation. Analysis involves the ability to recognize unstated assumptions, to distinguish facts from hypotheses, to distinguish a conclusion from statements that support it, to recognize which facts or assumptions are essential to a main thesis or to the argument in support of that thesis, to distinguish cause-effect relationships from other sequential relationships, and to recognize the point of view of a writer.

   Synthesis involves the production of a unique communication, the ability to propose ways of testing a hypothesis, the ability to design an experiment, the ability to formulate and modify a hypothesis, and the ability to make generalizations.

   Evaluation is defined as the making of judgments about the value of ideas, solutions, and methods. It involves the use of criteria as well as standards for appraising the extent to which details are accurate, effective, economical, or satisfying. Evaluation involves the ability to apply given criteria to judgments of work done, to indicate logical fallacies in arguments, and to compare major theories and generalizations.

The cognitive classification of examination questions may depend on the manner in which the content has been covered in the classroom. A question that is an application question for one class may be a knowledge question for another class.

Questions requiring knowledge and skill in the processes of science were included throughout the examination and are not associated with any specific topic or thought level.

Description of Subject Matter Areas and Sample Multiple-Choice Questions

The topics that were tested within each subject matter area are listed and sample questions from the test are provided. The correct response for each question is identified with an asterisk, and the percentage of students selecting each response is given.

1. Nature and Behavior of Light

Questions in this content area are related to reflection and refraction, propagation of light, interference and diffraction, dispersion, polarization, and deficiencies of the wave model. The specific topic statements covered by the examination were:

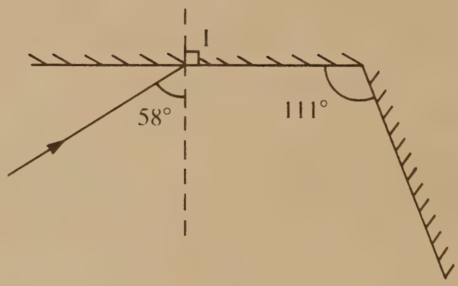
- Light travels in straight lines
- Olaf Römer gathered data to measure the speed of light
- Huygens calculated the speed of light
- The angle of reflection is equal to the angle of incidence
- Refraction involves a change of wavelength and speed as a wave goes from one medium to another
- Young showed that light rays produce interference patterns
- When a light ray is split into beams, interference results if two beams are allowed to overlap
- The longer a wave is compared to the size of an obstacle, the less it is scattered by the obstacle
- Part of Newton's argument is based on polarization of light
- The wave model requires that light travel through an ether

In the following example the students are required to make a prediction based on an understanding of principles related to the reflection of light from plane surfaces. To make the prediction, students must analyse the information provided in the diagram. This process is considered to be a higher mental activity.

Question 6:

Use the following information to answer question 6.

A ray of light hits the first mirror at point I and is reflected to the second mirror, where it is reflected again.



If the angle of incidence is 58° and the angle between the mirrors is 111°, then the angle between the final reflected ray and the second mirror is

<u>Student Responses</u>

10.3%	A.	53°
72.4%	*B.	37°
8.3%	C.	32°
9.0%	D.	11°
0.0%		no response

2. Electric and Magnetic Fields

Questions in this content area are related to moving charges and magnets, electric charges and forces, forces and fields, and moving charges. The specific topic statements covered by the examination were:

- The deflection of charged particles within a magnetic field
- Electric potential difference
- Power is a measure of the rate of change of energy
- Charles Coulomb provides direct experimental evidence for the inverse square law
- A charged body can influence the charges on another body
- The direction of the magnetic field surrounding a current-carrying conductor
- The amount and direction of deflection will depend upon the velocity of the particle and the value of the magnetic field strength
- To define a field it must be possible to assign a numerical value of field strength to every point in the field
- Robert Millikan showed that charges are made up of multiples of the smallest charge
- The field strength at any point is the ratio of the net gravitational force acting on a test body at that point to the mass of the test body
- Electric fields are similar to gravitational fields

- Electric and magnetic phenomena require one body being attracted to another by means other than by gravitational force
- Magnetic fields and moving charges

In the following example the students are required to apply knowledge related to the electric force law. Students must decide how the variables are related to the solution of the problem and relate these variables to one another.

Question 17:

Two charged objects, X and Y, separated by 0.40 m, exert a force of 4.0×10^{-6} N on each other. If the distance between X and Y were doubled, the electric force would be

<u>Student Responses</u>

8.4%	A.	1.6×10^{-5} N
10.0%	B.	8.0×10^{-6} N
30.0%	C.	2.0×10^{-6} N
51.5%	*D.	1.0×10^{-6} N
0.1%		no response

3. Electromagnetic Radiation

Questions in this content area are related to electromagnetic theory, the propagation of electromagnetic waves, evidence for the electromagnetic spectrum, and a description of the electromagnetic spectrum. The specific topic statements covered by the examination were:

- An electric current in a conductor produces magnetic lines of force that surround the conductor
- Energy and moving charges together produce radiation as an electromagnetic wave
- A changing electric field in space produces a magnetic field
- Electromagnetic waves have all the properties similar to light
- Infra-red or microwave radiation is in the range of 10^{-1} to 10^{-6} m
- X-rays can produce interference patterns which can be used to determine crystal structure
- Light, electric and magnetic propagations occur at the same speed and unify the separate sciences

In the following example the students are required to recall that in electromagnetic theory according to Maxwell, an electric field that varies over time will simultaneously induce a magnetic field that will also vary with time and will have a magnitude dependent upon the rate at which the electric field changes.

Question 28:

Maxwell proposed that a changing electric field generates

Student Responses

8.1%	A.	a constant magnetic field
2.6%	B.	a parallel magnetic field
83.9%	*C.	a changing magnetic field
5.4%	D.	an electric charge
0.0%		no response

4. Structure of Matter

Questions in this content area are related to the chemical and electrical nature of the atom, the quantum behavior of matter, the Rutherford-Bohr model of the atom, and the inadequacies of atomic models. The specific topic statements covered by the examination were:

- A magnetic field deflects the path of cathode rays
- Einstein explained the photoelectric effect
- Volta's electric cell made it possible to study the process of electrolysis
- In Millikan's oil-drop experiment the electric force on a particle is balanced by the force of gravity
- The law of definite proportions could be explained by Dalton's theory
- The ratio of the charge of a particle to its mass is denoted by q/m
- X-rays act like electromagnetic radiation of very short wavelength
- Scattering experiments interpreted by Rutherford led to the concept of the nuclear atom
- Only the spectrum of the hydrogen atom can be predicted accurately

In the following example the students are required to apply knowledge related to the chemical nature of the atom. Students must determine the relationship between variables of current, time, and mass of zinc in an electrolysis experiment and manipulate these to find the mass of a product.

Question 39:

In an electrolysis experiment, a current of x amperes flowing for y seconds produces 30 g of zinc. If a current of 3x is used for $y/2$ seconds, the mass of zinc produced will be

Student Responses

7.9%	A.	20 g
79.5%	*B.	45 g
4.2%	C.	90 g
8.4%	D.	180 g
0.0%		no response

5. Modern Physical Theories

Questions in this content area are related to the results of relativity theory, the particle-like behavior of radiation, the wave-like behavior of particles, the Schrödinger equation, and quantum mechanics. The specific topic statements covered by the examination were:

- Einstein proposed that mass and energy are equivalent
- Relativistic mechanics suggests that the mass of a body should vary with speed
- The Compton effect was a successful demonstration of the momentum of a quantum
- Photons act both like particles of matter and waves
- Some wave properties of the electron can be measured
- Schrödinger developed an equation which defines the wave properties of electrons and predicts particle-like behavior

In the following example the students are required to apply knowledge related to the wave-like behavior of particles. Students must be able to solve for the wavelength using the de Broglie equation.

Question 52:

The de Broglie wavelength for an electron moving with a velocity of 2.0×10^{7} m/s is

Student Responses

3.4%	A.	2.7×10^{10} m
85.6%	*B.	3.6×10^{-11} m
8.9%	C.	1.8×10^{-23} m
2.0%	D.	4.6×10^{-38} m
0.1%		no response

6. Scientific Process Skills

The process skills covered by the examination were:

Classifying - the grouping of objects, concepts, or events on the basis of some observable properties to show similarities, differences, and/or relationships.

Inferring - the process of arriving at a tentative explanation or conclusion based on direct or indirect observations.

Predicting - the process of formulating a specific forecast of what a future observation will be. Predicting often involves interpolating and extrapolating.

Hypothesizing - the process of proposing a tentative explanation, based on observations or inferences, for the occurrence of a set of observations or events. Hypotheses must be testable in order to be valid.

Interpreting data - the process of recognizing patterns in data, identifying relationships between variables, and forming generalizations.

Controlling Variables - the process of deciding which variables or factors will influence the outcome of an experiment, situation, or event. In an experimental situation, the variables of interest are free to vary in response to variables over which the experimenter exercises control. Controlled variables are allowed to take on specific values.

Processing Data - the process of organizing rough data in a more compact and meaningful way (through ordering, rearranging, comparing), depicting data pictorially or graphically, and processing data mathematically (finding slopes, tangents, etc.) to facilitate interpretations.

In the following example of organizing and processing data the students are required to interpret or generalize the force relationship between two charged objects and then to calculate the difference in charges.

Question 23:

Two charged objects, each with a mass of 2.0×10^{-9} kg, accelerate in an electrical field of 4.0×10^{6} N/C. If the acceleration of one object is -3.2×10^{-3} m/s^2 and the acceleration of the other object is -1.92×10^{-3} m/s^2, the charges differ by

Student Responses

7.3%	A.	8e
16.2%	B.	6e
48.6%	*C.	4e
27.4%	D.	2e
0.5%		no response

Written-Response Questions

In this section, students were expected to communicate their answers clearly and identify steps in their solutions. Students were expected to give the correct number of significant figures in calculations and were required to include appropriate units in their final answers.

Each written-response question from the examination is given on the following pages along with an appropriate answer. The total marks possible for each question are shown, as is the average number of marks awarded. The distribution of marks awarded to students for each written-response question is shown in Table 6, Chapter 3.

Question 1 reflects a strong process emphasis incorporated into an item in which students are required to interpret data from a variation on Young's double-slit experiment in order to identify and control variables that will show the relationship between wavelength and distance between consecutive bright lines.

In a variation on Young's double-slit experiment, students attempt to determine the effect of slit separation and source wavelength on the distance between consecutive bright lines of the resulting interference pattern.

a. A DEPENDENT (responding) variable in this experiment is

Key: distance between consecutive bright lines

b. An INDEPENDENT (manipulated) variable in this experiment is

Key: slit separation or source wavelength

c. Name one other variable that could be investigated by the students as having a direct effect on the distance between consecutive bright lines.

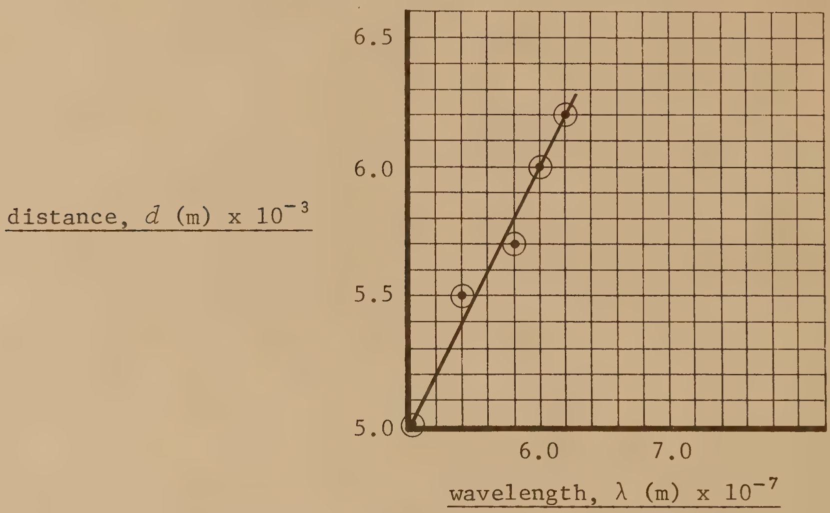
Key: distance between slit and screen

As a result of their experiment, the students recorded the following data on the relationship between the wavelength and distance between consecutive bright lines.

Wavelength (m)	Distance Between Consecutive Bright Lines, Δx (m)
5.0×10^{-7}	5.0×10^{-3}
5.4×10^{-7}	5.5×10^{-3}
5.8×10^{-7}	5.7×10^{-3}
6.0×10^{-7}	6.0×10^{-3}
6.2×10^{-7}	6.2×10^{-3}

d. On the grid provided, show the relationship between the two variables. Be sure to label both axes.

Key:



NOTE: Axes may be interchanged without loss of marks.

It was possible to score 5 marks for this question. The average number of marks awarded to students was 3.1.

Question 2 requires students to synthesize principles related to modern physical theories and the premise that kinetic energy given to mass results in a change in mass.

What is the relativistic mass of a proton with a kinetic energy of 2.00×10^2 MeV? Be sure to show ALL your calculations and the formulas that you use to solve this problem. Your answer must be expressed to the appropriate number of significant figures.

Key:

$$E = 2.00 \times 10^2 \text{ MeV} = 3.20 \times 10^{-11} \text{ J}$$

$$m = m_0 + E/c^2$$

$$m = 1.67 \times 10^{-27} \text{ kg} + 3.20 \times 10^{-11} \text{ J}/(3.00 \times 10^8 \text{ m/s})^2$$

$$m = 2.03 \times 10^{-27} \text{ kg}$$

The units for the answer in this case must be kg.

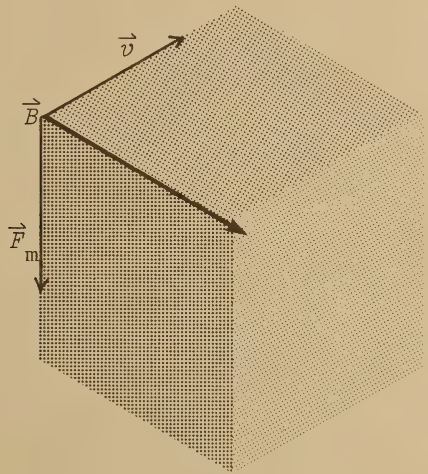
It was possible to score 3 marks for this question. The average number of marks awarded to students was 0.9.

Question 3 requires students to show the perpendicular relationship between $\vec{F}$, $\vec{B}$, and $\vec{v}$ and to calculate the magnitude of the force in the relationship $F = qvB_{\perp}$, where $\vec{B}$ and $\vec{v}$ are at right angles to each other.

A proton enters a uniform magnetic field at an angle of 90° to the field. The proton is travelling at a speed of 2.0×10^5 m/s, and the strength of the magnetic field is 1.4 T.

a. On the three-dimensional grid below, draw a vector diagram of the situation described above, indicating vectors for $\vec{v}$ and $\vec{F}$.

Key:



NOTE: This is only one of the solutions accepted which reflects use of the right hand rule.

b. What is the magnitude of the force experienced by the proton?

Key: $F = qvB_{\perp}(1.60 \times 10^{-19}\text{ C})(2.0 \times 10^5\text{ m/s})(1.41\text{ T}) = 4.48 \times 10^{-14}\text{ N}$

c. What is the direction of the force experienced by the proton?

Key: Downward, $\vec{F}$ is perpendicular to both $\vec{v}$ and $\vec{B}$ (indicative of the right hand rule used in part a).

It was possible to score 4 marks for this question. The average number of marks awarded to students was 1.7.

Question 4 requires students to make an inference regarding the mass of a single item based on the given results of an experiment. The remainder of this question asks students to identify the famous physicist associated with this analogous experiment and to give one conclusion regarding elementary particles derived from the experiment.

> The masses of several boxes containing identical items were determined. Each of the boxes was the same mass. The number of items in any given box was unknown.
>
> The following results were obtained.

Box Number	Mass of Box and Contents (g)
1	1.05
2	2.10
3	1.25
4	2.65
5	3.10
6	6.55
7	3.25
8	4.65
9	4.20
10	1.95

a. Without knowing the mass of the box or the number of items in any box, what may be inferred concerning the mass of a single item?

Key: The mass of a single item is 0.05 g, with the contents of each box being a multiple of this value.

b. The activity described above is analogous to a historic experiment related to one of the elementary particles. Name the physicist associated with the experiment.

Key: Millikan

c. State one conclusion regarding one of the elementary particles that was derived from the historic experiment.

Key: Charge is assumed to be quantized with the smallest unit being 1.6×10^{-19} C.

It was possible to score 3 marks for this question. The average number of marks awarded to students was 1.5.

CHAPTER 3

Results

Validity and Reliability

The content validity of the examination was established by the procedure for examination development outlined in Chapter 2. Each question was mapped to a specific topic statement defining some aspect of the curriculum. The Examination Review Committee evaluated each question, and the examination as a whole, for content validity.

The KR-20 coefficient for the multiple-choice portion of the examination was 0.89, and Cronbach's alpha for the total test was 0.92. These values are very satisfactory for an achievement test measuring a broad range of concepts and skills.

The inter-marker reliability for the marking of the written-response questions was also examined. The marking key for each question was prepared by the Student Evaluation Branch and then revised following discussion with four head markers. During the orientation session, teachers marked three common student responses for each question and discussed the awarding of marks. All teachers then marked an additional three student responses for each question so that the consistency of the marking procedures could be checked. At the beginning of each morning and afternoon marking session, all teachers marked two common student responses for each question. Any discrepancies were again discussed. For questions on those papers marked by all teachers, 92.2% of the marks awarded were in agreement, 7.7% deviated from the consensus mark by one mark, and 0.1% deviated by more than one mark. During the marking, one teacher marked questions 1 and 4, while a different teacher marked questions 2 and 3 for each paper.

Provincial Averages

The classification of examination questions according to subject matter topic and cognitive level has been presented in Table 1, Chapter 2. Subtest scores were computed for each of the five subject matter topics, for the three cognitive levels, and for the questions requiring the application of scientific process skills. Table 2 contains the provincial averages for these subtests and for the total examination. In each case, an average is given for the written-response questions, the multiple-choice questions, and the combination of the two (total). Averages are based on raw scores, which are the number of marks obtained on each subtest. The total marks possible are identified for the written-response and multiple-choice components of each subtest. For the multiple-choice component of each subtest, the average in per cent is also given.

Averages are based on the results achieved by 4905 students. Differences between total averages and component averages are due to rounding.

Table 2

Provincial Averages for Subtests

Subtest	Total Marks Possible		Raw Score Averages		
	Written-Response	Multiple-Choice	Written-Response	Multiple-Choice	Total
<u>Topics</u>					
Nature and Behavior of Light	5	11	3.1	8.1 (73.4%)	11.2
Electric and Magnetic Fields	4	14	1.7	8.6 (61.6%)	10.3
Electromagnetic Radiation	0	11	--	7.3 (66.3%)	7.3
Structure of Matter	3	11	1.5	7.6 (69.5%)	9.1
Modern Physical Theories	3	8	0.9	5.5 (69.3%)	6.4
Process Skills	8	8	4.6	4.9 (60.9%)	9.5
<u>Taxonomic Levels</u>					
Knowledge	0	23	--	15.7 (68.3%)	15.7
Application and Understanding	12	24	6.3	16.3 (67.9%)	22.6
Higher Mental Activities	3	8	0.9	5.1 (64.2%)	6.0
Total Examination	15	55	7.2	37.2 (67.6%)	44.4

The standard deviation for the total examination was 12.4 raw score points.

Total marks possible in Table 2 may differ from those given in Table 1 because written-response questions that cover more than one subject matter area have been allocated to only one subtest for reporting purposes.

The multiple-choice averages in per cent provide an indication of how well students performed within subject matter topics and taxonomic levels. There are no large differences in the averages for the five topics. The average for the six multiple-choice questions involving higher mental activities was considerably below the average for the multiple-choice portion of the test. The difficulty of these questions was likely the result of the complexity of the information that the students had to manipulate in order to answer them.

It is not meaningful to compare total subtest scores or written-response subtest scores across topics or taxonomic levels because of the uneven distribution of written-response questions. However, jurisdictions and schools can compare their averages to the provincial averages to help identify strengths and weaknesses in their programs.

Comparison of Multiple-Choice and Written-Response Questions

The average mark attained on the multiple-choice section of the examination was 67.6%, and the average mark attained on the written-response section was 47.9%.

In this section, each written-response question is discussed in relation to comparable multiple-choice questions.

In written-response question 1, the average number of marks awarded was 3.1 out of a possible 5 marks. This question required students to understand the relationship between slit separation, source wavelength, and distance between consecutive bright lines in a variation on Young's double-slit experiment.

Question 1 can be compared with multiple-choice questions 3 and 5, as they are similar with respect to type and complexity of calculations required.

Comparable Questions	Difficulty Levels
written-response 1	0.63
multiple-choice 3	0.68
multiple-choice 5	0.61

There was very little difference in performance and related difficulty of the written-response question and multiple-choice questions even though marks awarded are directly related to successful performance of process skills. In parts a and b, students were required to identify the independent and dependent variables within the context of the experiment described. In part d, students were required to process the data by graphing. They were required to assign variables to the x and y axes, include unit definitions with axes labels, and show the relationship between the variables. Student performance on the subsections of each written response item is included in Table 7.

In written-response question 2, the average number of marks awarded was 0.9 out of a possible 3 marks. Both written-response question 2 and multiple-choice questions 49 and 50 refer to results of relativity theory.

Comparable Questions	Difficulty Levels
written-response 2	0.30
multiple-choice 49	0.74
multiple-choice 50	0.69

The greater difficulty of written-response question 2 may be due to the extra component that requires the student to synthesize relationships of kinetic energy and relativistic mass. This higher mental activity seemed to pose problems that did not occur when these two concepts were presented as separate applications in the multiple-choice questions.

In written-response question 3, the average number of marks awarded was 1.7 out of a possible 4 marks. It is difficult to compare this written-response question to any single multiple-choice question because of its application to a unique representation in 3a, however, multiple-choice questions 18 and 19 deal with the same knowledge components.

Comparable Questions	Difficulty Levels
written-response 3	0.42
multiple-choice 18	0.77
multiple-choice 19	0.77

It would appear from the difficulty levels that students know the concepts involved, but experience problems applying them.

In written-response question 4, the average number of marks awarded was 1.4 out of a possible 3 marks. Both written-response question 4 and multiple-choice question 40 refer to Millikan's oil-drop experiment.

Comparable Questions	Difficulty Levels
written-response 4	0.48
multiple-choice 40	0.77

The greater difficulty of written-response question 4 may be due to the process skill component, which requires the student to draw an inference from the situation described.

Standard-Setting

Every effort was made to design a Physics 30 diploma examination that would be a valid and reliable measure of what students can be expected to know as a result of instruction in this course. A specific standard or level of expectation inherent in the examination was established through careful test development procedures.

To ensure equitability among marks awarded to students during the administration of each examination form for 1984, the Student Evaluation Branch adopted a process of standard-setting. One way to review the standards inherent in each examination was to involve classroom teachers in making judgments about the difficulty of the examination.

The teachers who marked the written-response portion of the examination reviewed the difficulty level of each question in terms of borderline passing students (who merit 50%). A judgment was also made regarding borderline "B" students (who merit 65%), and borderline "A" students (who merit 80%). After teachers made their initial judgments on question difficulty, they were given information about the actual distribution of students' examination marks. They were then given the opportunity to modify their judgments.

On the basis of the data derived from the standard-setting procedure and an inspection of school-awarded marks, it was decided that transformation would not be required.

Relationship Between Examination Mark and School Mark

The provincial averages and standard deviations for the school-awarded mark, the examination mark, and the final blended mark are presented in Table 3.

Table 3

Summary Statistics for School Mark, Examination Mark, and Final Mark

	School-Awarded Mark	Examination Mark	Final Blended Mark
Average	67.0%	63.9%	66.2%
Standard Deviation	13.4%	17.6%	14.6%

The average school mark was 3.1% higher than the average examination mark. The correlation between school marks and examination marks was 0.73, which indicates a fairly close agreement in the rank-ordering of the students based on the two sets of marks.

The percentages of students receiving A's, B's, C's, and F's are presented in Table 4 for the school mark, examination mark, and the final blended mark.

Table 4

Percentages of Students Receiving A's, B's, C's, and F's

Score	School-Awarded Mark	Examination Mark	Final Blended Mark
A(80-100%)	22.1	21.9	20.1
B(65-79%)	36.9	28.4	34.9
C(50-64%)	32.1	27.5	33.9
F(0-49%)	8.9	22.2	11.1

Results for Individual Questions

Multiple-Choice Questions

The percentage of students choosing each response for each multiple-choice question (item) is given in Table 5. The correct response (key) for each question is also identified.

Table 5

Results for Individual Multiple-Choice Questions

Item	Key	Distribution of Responses in %* A	B	C	D	Item	Key	Distribution of Responses in %* A	B	C	D
1	A	80.7	6.2	4.9	8.2	29	B	5.1	90.7	2.6	1.5
2	C	2.4	6.6	76.6	14.3	30	A	64.9	15.8	17.0	2.3
3	C	4.7	20.6	67.6	6.9	31	A	66.5	3.2	7.2	23.1
4	A	68.5	6.1	6.1	19.3	32	B	4.0	72.2	12.1	11.6
5	A	61.0	19.0	15.0	4.9	33	B	15.8	66.9	3.6	13.7
6	B	10.3	72.3	8.3	9.0	34	A	30.5	53.9	13.3	2.1
7	B	5.3	81.5	3.0	10.1	35	B	4.7	79.8	13.4	2.0
8	D	3.9	3.5	3.7	88.9	36	C	12.5	5.6	72.0	9.9
9	A	67.5	16.0	7.4	9.1	37	C	7.7	10.4	71.5	10.2
10	A	57.5	6.8	2.1	33.6	38	C	3.1	5.7	85.3	5.9
11	D	3.3	3.4	8.0	85.3	39	B	7.9	79.4	4.3	8.4
12	D	11.1	18.3	7.9	62.7	40	A	76.9	16.7	6.0	0.4
13	C	9.2	18.8	63.2	8.8	41	D	13.2	2.6	30.9	53.3
14	B	4.1	69.6	21.7	4.4	42	C	9.4	14.4	62.0	14.1
15	C	16.2	22.9	53.3	7.6	43	D	4.6	11.4	9.8	74.0
16	D	23.6	10.4	21.4	44.5	44	D	30.1	3.2	4.7	62.0
17	D	8.4	10.1	29.9	51.5	45	B	9.0	62.1	19.7	8.5
18	C	11.4	2.7	76.8	9.0	46	D	14.5	5.0	22.3	58.1
19	A	76.6	8.4	10.1	4.9	47	A	80.1	3.4	10.9	5.6
20	A	76.0	7.8	11.5	4.4	48	D	5.7	3.9	11.8	78.5
21	B	6.4	75.9	8.2	9.6	49	D	5.8	10.3	9.6	74.1
22	B	25.5	42.8	17.0	14.6	50	B	10.5	68.7	15.4	5.2
23	C	7.2	16.2	48.6	27.4	51	D	5.9	16.2	0.8	77.1
24	A	79.8	8.0	4.8	7.4	52	B	3.4	85.6	8.9	2.0
25	D	31.5	8.7	18.8	41.0	53	A	62.7	16.3	9.8	10.9
26	C	4.4	4.3	66.9	24.3	54	D	35.0	11.0	10.6	42.9
27	D	16.8	21.8	26.7	34.6	55	C	5.8	19.0	64.5	8.5
28	C	8.0	2.6	83.9	5.5						

*The sum of the percentages for each question may be less than 100% because the No Response category is not included.

Written-Response Questions

The percentage of students awarded each mark for each question is given in Table 6.

Table 6

Distribution of Marks for Written-Response Questions

Question Number	Percentage of Students Obtaining Each Mark				
	NR*	0	1	2	3
1a	2.2	46.6	51.2		
1b	2.4	22.4	75.2		
1c	4.9	31.1	64.0		
1d	2.3	14.5	41.8	41.3	
2	9.6	31.6	40.6	5.4	12.8
3a	12.6	34.5	21.8	31.1	
3b	15.1	29.7	55.1		
3c	11.4	59.8	28.8		
4a	7.6	69.4	23.0		
4b	7.2	22.4	70.4		
4c	14.3	33.6	52.0		

*NR - No Response

The total number of marks possible, the average mark awarded to students, and the difficulty level for each written-response question are summarized in Table 7. The difficulty level is the average divided by total marks possible.

Table 7

Average Marks Awarded for Written-Response Questions

Question Number	Total Marks	Average	Difficulty Level
1 (total)	5	3.1	0.63
1a	1	0.5	0.51
1b	1	0.8	0.75
1c	1	0.6	0.64
1d	2	1.2	0.62
2	3	0.9	0.30
3 (total)	4	1.7	0.42
3a	2	0.8	0.42
3b	1	0.6	0.55
3c	1	0.3	0.29
4 (total)	3	1.4	0.48
4a	1	0.2	0.23
4b	1	0.7	0.70
4c	1	0.5	0.52